

Development of a Smartphone Application for Dental Biofilm Control for Adolescents undergoing Fixed Orthodontic Treatment

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Abstract— *This work is aimed at the development of an electronic quiz-style game, available as an application for smartphones. The game was developed by a multidisciplinary team composed of dentistry and information technology professionals, who created a method of education compatible with the adolescent public, aiming to reduce oral problems arising from the prolonged use of fixed orthodontic appliances. As a result, a game was available free of charge at the smartphone application store, firstly tested by a team of orthodontics and periodontics clinicians, as well as computer professionals, who approved the quality and quantity of information provided to users as well as the usability of the application and clarity in the functions for the target audience.*

I. INTRODUCTION

During adolescence, the individual is amid biological and psychosocial changes¹. This phase is also marked by a decrease in care by parents and sometimes negative influence from the media and their social groups, resulting in conditions that are unfavourable to the teenager's general and oral health^{2,3}. The adolescent population represents 29% of the world population, 80% of which are in developing countries like Brazil, which, in 2019, had about 21 million young people⁴. As observed in clinical practice and reported in other studies, adolescent patients have a high rate of oral diseases, such as periodontal disease, caries, and halitosis⁵⁻⁷.

According to Souza *et al.*^{8,9}, health education is the most effective strategy to combat and prevent oral pathologies, considering that adolescents can acquire habits for the promotion, recovery, and maintenance of their health through information and learning activities.

Teenagers have access to a variety of digital media, through which they seek communication and entertainment. These digital resources can also be presented as electronic games and are part of their lives; therefore, their potential as a teaching and learning tool that could be explored^{10,11}.

Often, the oral hygiene of patients undergoing fixed orthodontic appliance is deficient, and clinical practice shows that teenagers are the most affected group. Therefore, the development of a tool was necessary to assist in oral hygiene habits and avoid the formation of bacterial plaque on the teeth and around the brackets, which is the leading cause of gingival inflammation and carious lesions. Also, the application was programmed to give specific advice and tips to adolescent patients on the correct use, care, and maintenance of the device.

Hygiene habits should be carried out according to the professionals' instructions, considering that biofilm control strategies must be adapted to individual needs.

However, not all patients have proper access to information, and when they do, many of them do not follow the recommendations due to the difficulties of daily life. Thus, the need for the creation and clinical trial of a smartphone application for correct orthodontic appliance and oral cavity hygiene guidance, with notification functions so that patients have better control of the distribution of the oral care measures throughout their day.

II. MATERIAL AND METHOD

This paper describes the creation and evaluation of an application for smartphones to improve the oral hygiene of adolescent patients undergoing orthodontic treatment using fixed braces. The purpose of creating the device was to strengthen its users' engagement towards the treatment to improve their oral hygiene.

The present work is a laboratorial research based on enhancing teaching and learning from the use of electronic games. The Research Ethics Committee approved this research of Paulista University (UNIP), São Paulo/Brazil, under protocol number 86135318.6.0000.5512.

The oral health electronic game entitled ORTODONTECH was developed by a multidisciplinary team of professionals from dentistry, computer engineering, and information technology.

The smartphone application containing the quiz-style game was developed in several stages, as described below.

1. DEVELOPMENT

Since the development of a game requires several areas of knowledge, a multidisciplinary team of developers has been made necessary. The team was composed of computer

engineering and information technology professionals in, responsible for the computational technical development itself, and dental orthodontics and periodontics professionals, who took the role of developing the theoretical content of the game. The creation process was organized from weekly meetings with all development team members, in which activities were assigned to the developers, pending activities, and difficulties were discussed. The game was developed over 6 months. The process for the development of this application consisted of the following steps:

- 1.1 Need analysis, reported by clinical situations and supported by the literature¹²⁻¹⁷.
- 1.2 Initial project (Mock-ups) and prototype, developed by information technology professionals. (Figure 1).
- 1.3 Design and pre-development, discussed together with the entire team to reach a consensus about language, information, and visual aspects, given the target audience.
- 1.4 Development and implementation of the application, meeting all legal requirements and privacy policies required by Google Play.
- 1.5 Technical evaluation, when dental and information technology professionals used the application to verify the usability, quantity, and quality of information and check how intuitive the features are given the target audience.
- 1.6 Test phase (future step – phase 2 of the project), in which the game will be applied to a clinical sample to test its effectiveness, in contrast to a control group.
- 1.7 Launching phase (future step – phase 3 of the project)

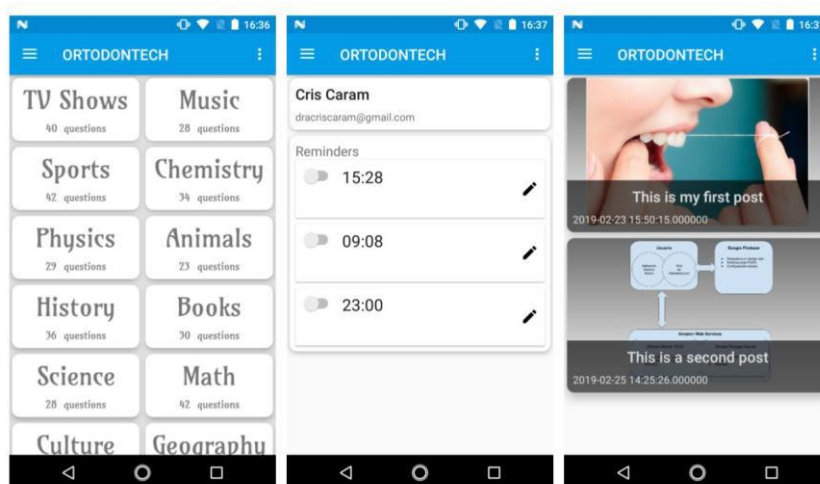


Fig. 1. Ortodontech prototype showing the quiz function, notifications settings, and posts of videos and educational diagrams

An Amazon Web Services (AWS) cloud infrastructure was used to host the services required by the application, such as

Route 53, for Domain Name Server (DNS) Service, EC2 (cloud service that provides secure and scalable computing

capacity in the cloud), and S3 (cloud data storage service). The Firebase Auth service (Google) was used as a user authorization layer.

The application was initially developed in a native environment for Android devices with the Android Studio tool, available for Marshmallow and later versions. The intention is to replicate all actions for IOS devices once the effectiveness of using the application has been clinically tested.

2. TECHNICAL EVALUATION

During this stage, the game was tested by the development team and other volunteer professionals to verify the correct functioning of all the inserted functionalities, usability and gameplay, and the quality and quantity of information made available to the user. For that, a test was applied based on the educational games evaluation method EGameFlow, an evaluative scale to measure the satisfaction and learning of the games¹⁸.

2.1 Sample

The sample consisted of four orthodontists and three periodontists with more than five years of clinical experience, one computer engineer, and two information technologists (n = 10). The computer engineer, two orthodontists, and one periodontist are part of the

application creation team, while the other professionals participated in the evaluation process voluntarily. Participants should sign the informed consent form and have access to a smartphone with an internet connection and Android operating system to join the assessment team.

2.2 Test

To test the game, examiners received a link via email, which directed them to the application. They were invited to browse the functionalities for 30 minutes to answer an evaluation questionnaire later.

2.2 Questionnaire

EGameFlow¹⁸ is a tool developed for the evaluation of electronic games and applications. The Likert-type scale (which assigns scores from 1 to 7 for each item, with one being the lowest and seven being the highest) has 56 items distributed over eight dimensions. The following are evaluated: (1) concentration (8 items), (2) clarity of objectives (5 items), (3) feedback (6 items), (4) challenge (10 items), (5) autonomy (9 items), (6) immersion (7 items), (7) social interaction (6 items) and (8) knowledge acquisition (5 items), as explained in chart 1. The tool was validated by five different tests and is frequently used by authors in testing new apps and serious games¹⁹⁻²².

Chart 1. EGameFlow: Brief explanation of each of the 56 topics evaluated by the examiners, as published by Fu et al. (2009)

Factor	Item	Content
Concentration	C1	The game grabs my attention
	C2	The game provides content that stimulates my attention
	C3	Most of the gaming activities are related to the learning task
	C4	No distraction from the task is highlighted
	C5	Generally speaking, I can remain concentrated in the game
	C6	I am not distracted from tasks that the player should concentrate on
	C7	I am not burdened with tasks that seem unrelated
	C8	Workload in the game is adequate
Goal clarity	G1	Overall game goals were presented at the beginning of the game
	G2	Overall game goals were presented clearly
	G3	Intermediate goals were presented at the beginning of each scene
	G4	Intermediate goals were presented clearly
	G5	I understand the learning goals through the game
Feedback	F1	I receive feedback on my progress in the game
	F2	I receive immediate feedback on my actions
	F3	I am notified of new tasks immediately

	F4	I am notified of new events immediately
	F5	I receive information on my success (or failure) of intermediate goals immediately
	F6	I receive information on my statuses, such as score or level
Challenge	H1	I enjoy the game without feeling bored or anxious
	H2	The challenge is adequate, neither too difficult nor too easy
	H3	The game provides "hints" in text that help me overcome the challenges
	H4	The game provides "online support" that helps me overcome the challenges
	H5	The game provides video or audio auxiliaries that help me overcome the challenges
	H6	My skill gradually improves through the course of overcoming the challenges
	H7	I am encouraged by the improvement of my skills
	H8	The difficulty of challenges increase as my skills improved
	H9	The game provides new challenges with an appropriate pacing
	H10	The game provides different levels of challenges that tailor to different players
Autonomy	A1	I feel a sense of control of the menu (such as start, stop, save, etc.)
	A2	I feel a sense of control over actions of roles or objects
	A3	I feel a sense of control over interactions between roles or objects
	A4	The game does not allow players to make errors to the degree that they cannot progress in the game
	A5	The game supports my recovery from errors
	A6	I feel that I can use strategies freely
	A7	I feel a sense of control and impact over the game
	A8	I know the next step in the game
	A9	I feel a sense of control over the game
Immersion	I1	I forget about time passing while playing the game
	I2	I become unaware of my surroundings while playing the game
	I3	I temporarily forget worries about everyday life while playing the game
	I4	I experience an altered sense of time
	I5	I can become involved in the game
	I6	I feel emotionally involved in the game
	I7	I feel viscerally involved in the game
Social interaction	S1	I feel cooperative toward other classmates
	S2	I strongly collaborate with other classmates
	S3	The cooperation in the game is helpful to the learning
	S4	The game supports social interaction between players (chat, etc.)
	S5	The game supports communities within the game
	S6	The game supports communities outside the game

Knowledge improvement	K1	The game increases my knowledge
	K2	I catch the basic ideas of the knowledge taught
	K3	I try to apply the knowledge in the game
	K4	The game motivates the player to integrate the knowledge taught
	K5	I want to know more about the knowledge taught

III. RESULTS

The scores obtained for EGameFlow questionnaire, attributed by the ten examiners, were recorded on Excel (Microsoft, 2010), and the mean and standard deviations were calculated as shown in Table 1.

Among some evaluation items, proposed by the EGameFlow method, the following were considered for the Ortodontech game:

- Concentration: the game attracted the players' attention, who considered the number of tasks to be adequate. Most of the game's tasks are tied to the educational objective.
- Clarity of Objectives: the player can understand the educational objectives through the game. The general objectives are presented.
- Feedback: the player receives feedback on his or her

progress and performance and is notified of new tasks as soon as he or she fulfils other challenges. The player receives information about scores through positioning in a ranking. (figure 2).

- Challenge: the player experiences the game without feeling too bored or anxious. The difficulty is adequate, without being too easy or too difficult.
- Autonomy: users can control the menu (such as "Start", "Stop", "Save" options), and the game supports the player's errors, clarifying the answers that may be wrong.
- Immersion: the player feels emotionally involved with the game, as it is related to his health.
- Improvement of Knowledge: the game can improve the players' knowledge, allowing them to assimilate the basic ideas of the taught content and apply it in their daily life.

Table 1. Mean and standard deviation (SD) for each item evaluated by the ten professionals through EGameFlow, concerning the Ortodontech application

Factor	Item	Mean	SD
Concentration	C1	4.2	0.6
	C2	4.3	0.6
	C3	4.9	0.7
	C4	5.3	0.5
	C5	5.1	0.5
	C6	4.8	0.4
	C7	6.1	0.7
	C8	4.7	1.1
Goal Clarity	G1	5.1	0.9
	G2	5	0.9
	G3	5.2	0.4
	G4	5.6	0.8
	G5	5.6	0.5
Feedback	F1	5.4	0.5
	F2	5.8	0.6
	F3	5.5	0.5
	F4	5.3	0.5
	F5	5.8	0.7
	F6	4.5	0.7

Challenge	H1	4.8	0.6
	H2	4.9	1.1
	H3	5.3	0.6
	H4	4	0.4
	H5	5.6	0.5
	H6	5.5	0.5
	H7	4.8	0.7
	H8	4.7	0.6
	H9	4.4	0.7
	H10	4.9	1.0
Autonomy	A1	4.3	0.9
	A2	4.5	0.5
	A3	4.4	0.7
	A4	4.7	0.6
	A5	5	0.6
	A6	4.7	0.5
	A7	4.7	0.5
	A8	4.7	0.6
	A9	5	0.8
Immersion	I1	4	0.4
	I2	3.9	0.5
	I3	3.9	0.5
	I4	4.3	0.6
	I5	4.5	0.7
	I6	4	0.8
	I7	3.7	0.5
Social Interaction	S1	3.4	0.8
	S2	3.8	0.4
	S3	4.2	0.7
	S4	3.5	0.5
	S5	3.4	0.5
	S6	3.5	0.5
Knowledge acquisition	K1	5.1	0.5
	K2	5.7	0.6
	K3	5.2	0.6
	K4	5	0.4
	K5	5.2	0.6
Total scale		4.8	0.8

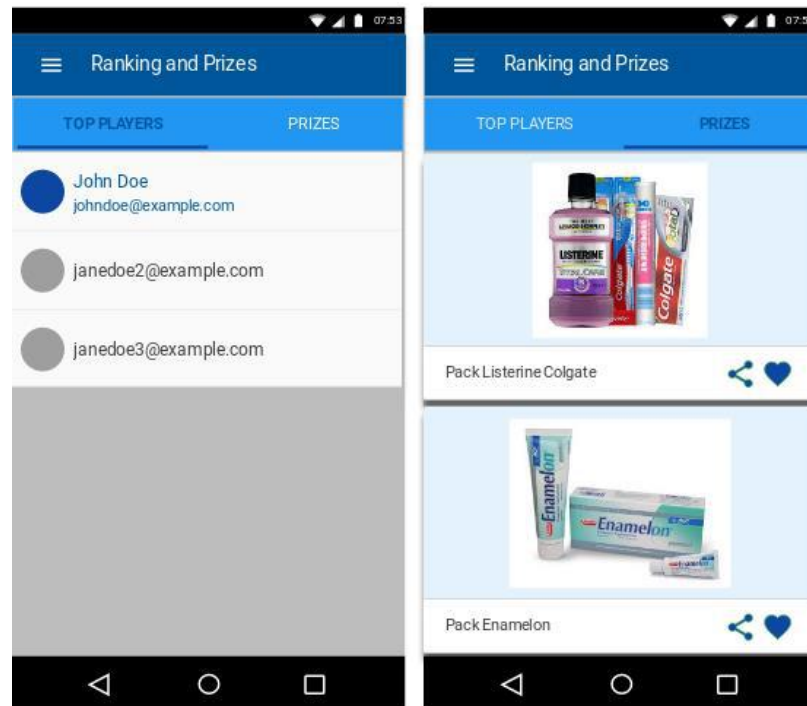


Fig. 2. Player's feedback with ranking position, which may be linked to a reward system

IV. DISCUSSION

The educational potential of electronic games refers to the ability to stimulate a series of fundamental conditions for absorbing information, such as attention, involvement with the educational activity, and cognitive ability. The playful character and the multiplicity of sound and visual stimuli hold the 'players' attention to a particular event occurring in the game, preventing them from diverting their attention. In addition, the effort required to achieve a certain objective of the game promotes engagement with the proposed tasks, leading the player to acquire knowledge^{23,24,26,27}.

When analysing the performance of Ortodontech, one can observe a good general score, but, above all, high scores in terms of knowledge acquisition, clarity of objectives, and feedback. It is understood that a serious game has as main objective to assist in the transmission of educational content or to train the user to perform a particular task with greater precision and autonomy²⁶. Within this context, Ortodontech may be used clinically as a serious game that can positively impact the hygiene habits of adolescents undergoing orthodontic treatment.

There are aspects to be improved in the application, such as social interaction and immersion in the game, although the importance of the user not being so immersed in the game may be debated, as to conflict with his or her daily routine and responsibilities.

Taking this into account, electronic games, especially those

developed as applications for smartphones, can and should be used as educational tools for teenagers since they are used to electronic media. Besides, the entertainment factors that are attributed to games facilitate the learning process. Another point that favours the use of games as an educational medium is the possibility of being continuously used, since its accessibility allows the player to contact the information daily, and without access restrictions. That offers a great advantage for the serious electronic games compared to the traditional means of health education, such as educational lectures, with information reaching the teenagers through annual health actions in schools; thus, the probability of little absorption of what was taught is very high^{25,27,28}.

V. CONCLUSION

Ortodontech is a helpful tool for patient engagement in treatment and greater responsibility awareness for their hygiene since the main objective of the application is to achieve a bond of commitment with the user, aiming to improve their oral hygiene practices. Although clinical applications are necessary, it is safe to say that the application can improve oral hygiene habits in adolescents using fixed appliances.

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